A new genus and new species of freshwater mussel from the mid Late Triassic rift lakes of eastern North Carolina (Bivalvia: Unionida: cf. Unionidae)

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ABSTRACT

In eastern North America, surface exposures of Triassic basins extend from Nova Scotia southwestward to South Carolina. This interrupted series of half-grabens resulted from early Mesozoic rifting of the supercontinent Pangaea. In south-central North Carolina, the Deep River basin is comprised of the Durham subbasin, the Colon cross-structure, the Sandford subbasin, the Pekin cross structure, and the Wadesboro subbasin. Deposits within the Durham subbasin are recognized as the Chatham Group, part of the Newark Supergroup and form part of a series informally designated as Lithofacies Association II. These strata are considered to be alternating fluvial and lacustrine sediments. Though research on the vertebrate fauna from this lithofacies has been ongoing for over a century, considerably less research, particularly in North Carolina, has been done on the lacustrine invertebrate fauna.

Ongoing field work at a brick-clay quarry in the village of Genlee, Durham County, North Carolina, has yielded three distinct forms of Triassic freshwater bivalves, one is considered here to be of the order Unionoida and the others tentatively a mytiloid in shell outline and a sphaeriid in shell outline. The unionoid specimens are assigned to *Triaslacus* new genus and *Triaslacus carolinesis* new species and are tentatively assigned to the Unionidae. These new specimens are compared with specimens described as belonging to the unionoid families Unionidae, Hyriidae, and Mulleriidae [+Mycetopodidae] from Massachusetts and Pennsylvania. However, none of the North Carolina specimens exhibit the umbonal sculpture exhibited by the northeastern specimens. The North Carolina unionoid specimens lack any evidence of hinge development or umbonal sculpture.

Non-unionoid bivalves are quite rare in these deposits. The bivalve fauna is found in association with ostracods of the genus *Darwinula;* clam shrimp, *Euestheria*, represented by carbonized impressions of the shells; and fish and plant remains. This freshwater environment is preserved in a mudstone or clayey siltstone sediments.

Additional keywords: Unionida, Uniomorphi, Newark Supergroup

INTRODUCTION

Freshwater bivalves in the Order Unionida have been placed in the Cohort Uniomorphi (=Paleoheterodonta), based on shell characters used to identify the sister relationship of Trigonida and Unionida (Weir, 1969; Bieler et al., 2010; Carter et al., 2011). Trigonida and Unionida are considered sister taxa in the Uniomorphi based initially on shell morphology and the presence of nacre. This relationship is supported by DNA analyses (Hoeh et al., 1998; Hoeh et al., 2001; Giribet and Wheeler, 2002; Taylor et al., 2007).

Subdivision of the Unionida has varied over the past hundred years from a single family to six modern families and various included fossil groups (e.g., Haas, 1969; Starobogatov, 1970; Carter et al., 2011). Taxonomic placement of fossil freshwater bivalves in modern extant families and genera is not supported. This practice is fraught with problems of convergence of shell morphology (Ortmann, 1912; Prashad, 1931; Hartman and Bogan, 2009). Allocations of bivalve taxa discussed here are based on shell shape and morphology and are considered tentative until there is a phylogenetic analysis of the modern and fossil Unionida.

History of North American bivalve fossils assigned to the Order Unionida was summarized by Henderson (1935) and more recently reviewed by Watters (2001). Triassic freshwater bivalves described from the eastern United States are primarily from Pennsylvania and Massachusetts (Table 1). North American Triassic freshwater bivalves described from the southwestern United States including Texas, New Mexico, Arizona, California, and Utah, are assigned to Unionidae and Hyriidae (Good, 1998).

Pilsbry (1921, 1926) placed the Triassic freshwater bivalve taxa from the northeastern United States in the modern South American families Mycetopodidae based on similarity of shell shape to the modern genus

Table 1. List of freshwater bivalves from the Triassic of the eastern United States.

Mulleriidae (+Mycetopodidae)
Mycepoda? diliculi Pilsbry in Wanner, 1921, Pennsylvania

Hyriidae
Diplodon borealis Pilsbry in Wanner, 1921; Pilsbry, 1926, Pennsylvania
Diplodon carolus-simpsoni Pilsbry in Wanner, 1921, Pennsylvania
Diplodon pennsylvanicus Pilsbry in Wanner, 1921, Pennsylvania
Diplodon wanneri Pilsbry in Wanner, 1921, Pennsylvania
Diplodon yorkensis Pilsbry, in Wanner, 1921 Richards 1944, Pennsylvania

Unionidae
Unio emersoni Troxell, 1914, Massachusetts
Anoplophora wilbrahamensis Emerson, 1900, Massachusetts [moved to *Unio* by Lull, 1915]
Unionidae sp. Bain and Harvey, 1977; Good, 1995a; Good, 1995b, North Carolina

Trace fossils (Lull, 1915, as Mollusks?; Henderson, 1935, as freshwater mussel trails).
Bisulcus undulatus Hitchcock, 1865, Massachusetts
Trisulcus laqueatus Hitchcock, 1865, Massachusetts

Mycetopoda, and Hyriidae based on radial umbo sculpture, similar to the modern genus *Diplodon*. Remaining taxa were described or moved to the genus *Unio* and assumed to belong in the family Unionidae.

Two trace fossils described by Hitchcock (1865) *Bisulcus undulatus* Hitchcock, 1865 and *Trisulcus laqueatus* Hitchcock, 1865, both from Massachusetts, were described as annelids. *Trisulcus* was listed as a worm track by Lesley (1890), who failed to list *Bisulcus*. Lull (1915, 1917) placed them in Mollusca? noting they differ from worms in being multiple-, double-, or triple-ridged trails. Both of these taxa were listed as possible tracks of freshwater mussels but with no further elaboration by Henderson (1935). There is some doubt that these represent tracks of freshwater mussels and not some other invertebrate.

GEOLOGICAL SETTING

The Deep River Basin, located in east-central North Carolina, resulted from early Mesozoic rifting of the supercontinent Pangaea (Clark et al., 2001). This north to northeast-trending half graben is about 226 km long and averages about 16 km in width (Bain and Harvey, 1977). Deposits of the Deep River Basin consist of varying amounts of conglomerate, sandstone, siltstone, claystone, shale, coal, and small amounts of limestone and chert (Clark et al., 2001). These deposits are recognized as the Chatham Group, part of the Newark Supergroup as defined by Olsen (1978) and Luttrell (1989). The Deep River Basin is bordered on the east by the Jonesboro fault, a west-dipping, high-angle normal fault (Campbell and Kimball, 1923). The Jonesboro fault separates Triassic sedimentary rocks of the basin from the Raleigh metamorphic belt and Carolina zone metavolcanics and metasediments (Clark et al., 2001). Minor faults form the basin's western border, where Triassic sedimentary rocks unconformably overlie Late Proterozoic and Cambrian metavolcanic and metasedimentary rocks (NCGS, 1985). Several minor faults have also been recognized throughout the basin. From north to south, the Deep River Basin is traditionally divided into four substructures: Durham subbasin, Colon cross-structure, Sanford subbasin, and the Wadesboro subbasin (Bain and Harvey, 1977). Some workers also recognize The Pekin cross structure between the Sanford and Wadesboro Basins (Clark et al., 2001).

Bivalves described herein were recovered by North Carolina Museum of Natural Sciences research staff and volunteers in the late 1990s and early 2000s from a brick/clay quarry in Durham County, North Carolina (Figure 1). The quarry is located in the northeast corner of the Green Level 7.5-minute Quadrangle at 35°52′14.12″ N latitude and 78° 53′51.77″ W longitude (coordinates are from Acme Mapper 2.0 http://mapper.acme.com/ on June 10, 2012 using WGS 84) in the village of Genlee, Durham County, North Carolina (Olsen and Huber, 1997). Strata in this quarry occur in the south-central part of the Durham subbasin of the Deep River Basin (Chatham Group of the Newark Supergroup) (Sues et al., 2003a), and form part of a series informally designated as Lithofacies Association II (Hoffman and Gallagher, 1989). Kozur and Weems (2007) placed this lithofacies in the Sanford Formation. The main quarry exposes about 60 m of red, purple and gray fissile to bioturbated massive mudstones interbedded with gray, brown and red arkosic sandstones (Olsen and Huber, 1997) and are considered by Hoffman and Gallagher (1989) to be a series of alternating fluvial and lacustrine facies. The recovery of the vertebrate *Aetosaurus* from the quarry provides a Norian age for the local section (Lucas et al., 1998). However, using conchostracan biostragraphy, Kozur and Weems (2007) determined a latest Tuvalian (Carnian) age for the section. As the conchostracans and unionoid bivalves come from layers well below the layers containing the vertebrates, it is possible that quarry sediments straddle the Carnian/Norian boundary.

A modified version of the exposed section at the quarry is given in Olsen and Huber (1997, fig. 3) and earlier versions of the section are given in Olsen (1977) and Olsen et al. (1989, 1991). From the fluvial facies of this quarry, Parker (1966) and Lucas et al. (1998) described a partial articulated skeleton of *Aetosaurus* (=*Stegomus*). Sues et al. (2003b) also reported an articulated rauisuchian, *Postosuchus* sp., with gut contents consisting of a partial skeleton of *Aetosaurus* (=*Stegomus*), limb bones of a juvenile traversodont, a partial dicynodont digit and a dermal bone of an indeterminate temnospondyl from one of the fluvial facies. Also, from that same lithofacies, beneath the torso of

Figure 1–6. Freshwater bivalves from the mid Late Triassic rift lakes of eastern North Carolina Triangle. **1.** Brick Quarry, Carpenter Plant brick pit. **2.** *Triaslacus carolinesis* holotype, NCSM 9169A, total shell length is 10.54 mm. **3.** *Triaslacus carolinesis*, partaypes, NCSM 10781, internal mold. Total shell length = 9.74 mm. **4.** *Triaslacus carolinesis*, specimen NCSM 11156, Cedar Run, Virginia. Total shell length = 8.94 mm. **5.** Possible Sphaeriidae? NCSM 10525. **6.** Possible Mytilidae? NCSM 10520.

the rauisuchian, Sues et al. (2003a) described an articulated skeleton of sphenosuchian crocodylomorph, *Dromicosuchus grallator*. The bivalves described herein come from one of the lower lacustrine facies. Faunal elements found in association with the bivalves include darwinulid ostracodes; the trace fossil *Scoyenia;* cambarid crayfish; fragmentary and articulated fish; occasional phytosaur teeth; and coprolites (Olsen and Huber, 1997). Also found in association with the bivalves, are conchostracans described by Kozur and Weems (2007) as *Euestheria buravasi*, *Euestheria* sp. cf. *E. hausmanni*, and *Anyuanestheria*? new species.

MATERIALS AND METHODS

All specimens used in this description are housed in the North Carolina State Museum of Natural Sciences, Invertebrate Paleontology section, herein abbreviated NCSM.

Shell measurements were made to the nearest millimeter using digital calipers and included total length and height. Total length was defined as distance between anterior and posterior margins, measured parallel to the hinge line. Shell height is distance between dorsal and ventral margins, measured near the midpoint of the hinge line, perpendicular to shell length.

SYSTEMATIC PALEONTOLOGY

Class Bivalvia
Cohort Uniomorphi (=Palaeoheterodonta of authors)
Order Unionoida

Family cf. Unionidae

Genus *Triaslacus* new genus

Type Species: *Triaslacus carolinensis* new species

Diagnosis: A small edentulous freshwater bivalve, oval in outline, lacking any umbonal sculpture.

Description: *Triaslacus* is distinguished from other fossil unionoid species by a combination of the following characteristics: Apparently thin, somewhat inflated, shell, elliptical outline; hinge teeth absent; umbo only slightly elevated above hinge line; umbo sculpture is absent. *Triaslacus* can be distinguished from other Triassic bivalves from northeastern United States assigned to the Unionida by the following combination of characters. It differs in shell shape from the elongate shell shape assigned to Mulleriidae or the more rectangular shape of species assigned to the Hyriidae. *Triaslacus* appear to have a smooth umbo at or only slightly above the hinge line, while other Triassic bivalve taxa have radial umbonal sculpture and are assigned to the Hyriidae. *Triaslacus* appears to be edentulous.

Distribution: Known from the Late Triassic rift lake deposits in North Carolina and Virginia.

Etymology: The genus name *Triaslacus* stands for the Triassic lake deposits where it was collected.

***Triaslacus carolinensis* new species**
(Figures 2–4)

Unionidae sp.—Bain and Harvey, 1977;
Good 1995a; 1995b.

Diagnosis: *Triaslacus carolinensis* is distinguished from all other known Late Triassic unionoid bivalves occurring along the east coast of North America by the oval shell outline in contrast to the elongate shell in species of *Mycetopoda*. It lacks the radial umbonal sculpture of *Diplodon* species and does not have the square shell outline of *Unio emersoni*.

Description: Length to 12.8 mm, height to 7.5 mm; shell thin, moderately inflated, outline oval. Posterior margin narrowly rounded to bluntly pointed. Anterior margin broadly rounded. Dorsal margin straight. Ventral margin convex. Posterior ridge rounded. Posterior slope moderately steep. Umbo broad, moderately inflated, barely elevated above hinge line. Umbo sculpture absent. Pseudocardinal and lateral hinge teeth absent. Umbo cavity wide, shallow.

Comparison with Similar Species: *Triaslacus carolinesis* shells do not resemble the shell referred to as *Mycepoda*? *diliculi* Pilsbry in Wanner, 1921and placed in the Mycetopodidae, which is nowadays considered to be restricted to South America. *Triaslacus carolinesis* does not have the radial umbonal sculpture of those taxa referred to the genus *Diplodon* (Table 1) and, by extension, to the family Hyriidae, today restricted to South America, Australia, New Zealand, and New Guinea. *Diplodon carolussimpsoni* from Pennsylvania is more rectangular in shell shape and has a well-marked posterior ridge. *Unio emersoni* is more elongate is shell outline, larger in maximum shell length and possess large hinge teeth, while *Triaslacus carolinesis* is smaller in size, more oval in shell outline and is edentulous. *Anoplophora wilbrahamensis* is more elongate oval in outline, larger in maximum shell length than *Triaslacus carolinesis* and has a long lateral tooth, while *T. carolinesis* is edentulous.

Type Material: Holotype, NCSM 9169, internal mold, both valves. Paratypes, NCSM 10747, negative relief; NCSM 10757, NCSM 10760, cluster; NCSM 10767, negative relief; NCSM 10769, NCSM 10778, positive relief; NCSM 10781, positive relief; NCSM 10790, positive relief. All from the type locality.

Type Locality: United States, North Carolina, Durham–Wake County, Triangle Brick, Carpenter Plant in the village of Genlee. Northeast corner of the Green Level 7.5′ quadrangle at 35°52′ 14.12″ N latitude and 78°53′ 51.77″ W longitude (coordinates are from Acme Mapper 2.0 http://mapper.acme.com/ on June 10, 2012) (Figure 1).

Other Material Examined: United States, North Carolina, Durham–Wake counties, Triangle Brick, Carpenter Plant: NCSM 5035.1-5035.9 all positive/negative; NCSM 5036, 38 specimens; NCSM 5037.1-5037.9, some are both positive/negative; NCSM 6135, total of 7 specimens; NCSM 10745–10746; NCSM 10748–10756; NCSM 10758–10759; NCSM 10761–10766; NCSM 10768; NCSM 10770–10780; NCSM 10782–10788; NCSM 10791; NCSM 10794–10818; United States, Virginia, Fauquier County, Carriage

Ford, Nokesville. Collector: Robert Weems coll. NCSM 11132–11139; United States, Virginia, Hanover County, Stagg Creek transect, Taylorsville Basin, Hannover Academy Quadrangle, Robert Weems coll.; NCSM 11140–11150; United States, Virginia, Fauquier County, Cedar Run. Catlett Quadrangle, Robert Weems coll., NCSM 11151–11158

Etymology: The species is named for the state of North Carolina, where the species was first collected.

Distribution: Triangle Brick Quarry Carpenter Plant, Gen Lee, Durham–Wake County, North Carolina. Carriage Ford, Nokesville, Fauquier County, Virginia. Stagg Creek transect, Taylorsville Basin, Hannover Academy Quadrangle, Hanover County, Virginia and Cedar Run, Catlett Quadrangle, Fauquier County, Virginia.

Stratigraphy: Mid Late Triassic (Carnian–Norian Stage interval) Newark Supergroup, Lithofacies II.

Habitat: *Triaslacus carolinesis* is found in similar sedimentary deposits bearing similar associated faunal elements in Durham County North Carolina, and Fauquier County, Virginia. Good (1995a,b) suggested the small or "dwarfed" size of the unionoid is due to "environmental conditions not optimum for this group, probably indicating a deep water lacustrine habitat." Small shell size is common in modern unionoids and some species are found at depths over 15 m and they are not dwarfed (Bailey and Green, 1989). The lake environment was likely rather shallow and soft bottomed, containing aquatic vegetation, associated fish, ostracods and clamshrimp. The latter species is found in lacustrine facies suggesting soft-bottomed deposits in quiet water similar to habits of the common modern thin-shelled eastern North American anodontine, *Utterbackia imbecillis* (Say, 1829).

Order Cardiida?

Family Sphaeriidae?
(Figure 5)

Description: Shell almost round in outline with some valve inflation, reminiseent of modern Sphaeriidae, None of the specimens have exposed hinge plates that would allow for family level confirmation (see Mackie, 2007).

Habitat: Sphaeriids occur today throughout the world in freshwater habitats similar to those described here for Lithofacies II.

Geologic History: Keen (1969) lists Late Jurassic? as the oldest record for the family Sphaeriidae. If correctly identified, this record would extend the geologic range of the family back to the Late Triassic.

Material Examined: NCSM 10521–10524, 10819, 11157, 11158, from Lithofacies II, Triangle Brick Quarry Carpenter Plant, Gen Lee, Durham–Wake County, North Carolina and Cedar Run, Catlett Quadrangle, Fauquier County, Virginia NCSM 11157–11160. Specimens 11157 and 11158 also have *Triaslacus* on the same block.

Cohort Mytilomorphi
Order Mytilida?

Family Mytilidae?
(Figure 6)

Description: Specimens with a mytilid shell shape, with umbo area very anterior and a rather elongate oval shape are tentatively referred to Mytilidae.

Geologic History: This family is reported as occurring from the Devonian to the Recent (Soot-Ryen, 1969).

Material Examined: NCSM10520, 10820–10822, Lithofacies II, Triangle Brick Quarry Carpenter Plant, Gen Lee, Durham–Wake County, North Carolina.

Remarks: Pilsbry (1926) described *Naiadites triassicus* Pilsbry in Wanner, 1926 and *Naiadites wanneri* Pilsbry in Wanner, 1926, recognizing that this genus was known from the Coal Measures [Upper Carboniferous] of Nova Scotia and far earlier than the Triassic deposits these specimens were collected. Weir (1969) placed *Naiadites* in the family Myalinidae.

Good (1995a, b) claimed that the identification of the small associated bivalves from these deposits are non-marine Myalinidae. As Good pointed out, they are not Cyrenidae (+ Corbiculidae), but some appear to resemble Mytilidae (Figure 6) and others Sphaeriidae (Figure 5). This does not, as yet [?], call for a Lazarus distribution between the Pennsylvanian and the Late Triassic.

DISCUSSION

Freshwater bivalves from the Durham subbasin and the Taylorsville Basin of Virginia are described here as a new genus and species of freshwater bivalve tentatively assigned to the family Unionidae. *Triaslacus carolinesis* differs from the Triassic freshwater bivalves described from Connecticut, Massachusetts, and Pennsylvania in shell outline, inflation and umbonal sculpture. *Triaslacus carolinesis* is only tentatively assigned to the Unionidae based on the shell outline, laek of radial umbonal sculpture and lack of hinge teeth. The ambiguity of family assignment is due to rampant shell shape convergence or shell homeomorphy in freshwater bivalves (Ortmann, 1912; Prashad, 1931; Watters, 1994)).

White (1907), writing on the origin of the North American fossil freshwater bivalve fauna before the work of Pilsbry (1921), felt that the modern unionoid fauna was probably derived from the Triassic fauna of the southwestern United States.

Pilsbry (1921) described Triassic freshwater bivalves for the northeast United States and suggested that this fauna is composed of taxa assigned to the modern families

Hyriidae and Mycetopodidae and suggested that probably all of the North American fossil Triassic freshwater bivalves were related to the South American fauna. He felt the hyriid mussels would have disappeared with the migration of "Old World forms in the Upper Trias or Jurassic".

Parodiz (1969) followed this line of reasoning and claimed the Hyriidae of the Triassic of North America migrated into South America in the Paleocene.

The evolution of freshwater bivalves in North America has most recently been summarized by Watters (2001), who agreed that Hyriidae occurred in North America in the Triassic. However, Watters does raise the problem of convergence in shell sculpture and notes the lack of shell characters to separate these fossils from the modern Hyriidae.

One of the five major extinction events occurred at the end of Triassic. Timing and extent of this extinction event is controversial, catastrophic vs. gradual (e.g. Olsen et al., 1987; Palfy et al., 2000; Hallam, 2002; Tanner et al., 2004; Deenen et al., 2010). Taking into consideration terrestrial extinctions at the end of the Triassic and the expanding rift zone along eastern North America, animals living in these rift lakes appear to have been slated for extinction. Triassic freshwater bivalves collected from the rift lakes of the eastern United States most likely represent an extinct radiation and as such, may not have any relation to the currently recognized six families in the Unionida and may not represent the origin of any of the modern Unionida families.

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